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MODIFIED SINGLE SURFACE TREATMENT USING 12-19 mm AND 4-9 mm STEEL SLAG AGGREGATE

by

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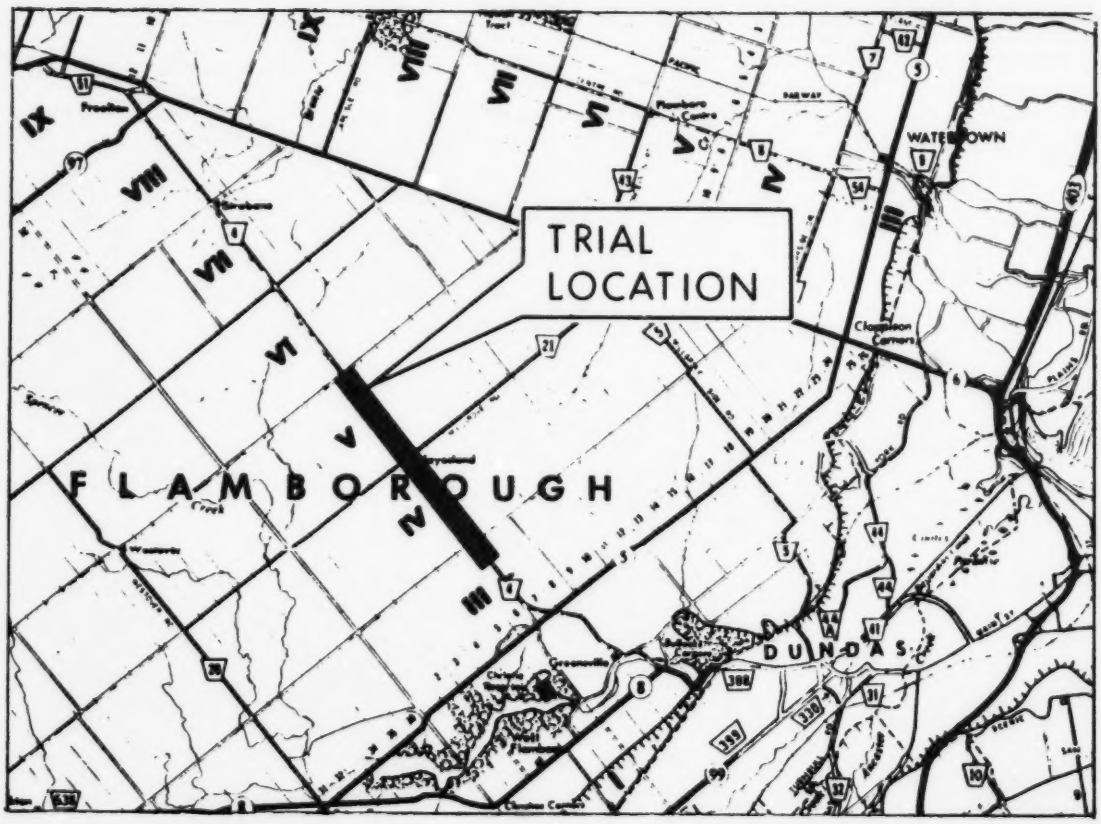


Trial Location - Region of Hamilton-Wentworth
Region Road No. 4

ABSTRACT

Surface treatments have been constructed with good results for many years on low volume roads. Today less money is being spent on new construction and more funds are being allocated to pavement maintenance and rehabilitation. The need exists for a surface treatment system which will produce a long wearing surface with good friction properties and which will withstand high volume traffic.

This report describes a trial installation of a modified single surface treatment system which consists of spraying one application of emulsified asphalt followed by two applications of aggregate, both aggregate applications being spread before rolling. The emulsified asphalt selected as the binder was CRS-2 and the aggregate selected was steel slag. For comparison purposes, a standard double surface treatment was constructed using the same materials, personnel and equipment. The work was constructed using standard surface treatment equipment with the addition of a rubber coated steel drum vibratory roller specifically designed for surface treatment work.

The purpose of the trial of this modified single surface treatment system was to assess the system as a cost saving alternative to the current practice of resurfacing highways with hot mix asphaltic concrete, and assess the new construction techniques and equipment.

A brief outline of design, construction procedures, observations and a cost comparison is included as well as a comparison of skid resistance, noise level and texture depth measurements of this modified system with the double surface treatment, standard single surface treatment and conventional hot mix resurfacing.

It has been concluded that this modified single surface treatment system

(1) can be constructed with no unusual problems.

(2) can be constructed with much less inconvenience to the travelling public than normal single surface treatment.

(3) provides better friction properties than standard hot mix pavement.

(4) results in a higher noise level than standard hot mix pavement.

(5) enjoys a considerable cost saving over the standard hot mix rehabilitation treatment.

It is recommended, pending further evaluation of the trial in 1983, that consideration be given to constructing a full scale project using this modified single surface treatment system with steel slag aggregate in lieu of hot mix resurfacing.

MODIFIED SINGLE SURFACE TREATMENT USING 12-19 mm AND 4-9 mm STEEL SLAG AGGREGATE

by R.C. Aquin, J.A. Cooper and D.F. Lynch

INTRODUCTION

Current economic conditions, budget limitations and anticipated cost increases in asphalt cement make it necessary to investigate cost saving options with respect to highway pavement resurfacing and to attempt to select a viable economical alternative to asphaltic concrete.

One option that deserves investigation and consideration is the construction of surface treatment in lieu of the current practice of conventional hot mix resurfacing. Surface treatment enjoys a considerable cost advantage when compared to hot mix resurfacing, as well as improved frictional characteristics providing improved safety. Present rehabilitation treatment is to construct a 25 mm levelling course of sand asphalt mix followed by a 40 mm surface course of dense graded asphaltic concrete. This report describes a surface treatment system which can be used to replace the surface course at an anticipated cost saving of approximately $12,000/km. When one considers that the Ministry's annual pavement resurfacing program is estimated to be 800 km, if 50% of this program could be changed to this new surface treatment system, it would result in an annual saving to the Ministry of $4,800,000.

BACKGROUND

Current Ministry practice is to confine surface treatment mainly to secondary highways with relative low (< 1000 AADT) traffic volumes. Surface treatment is applied to existing primed surfaces, old surface treated roads and newly graded and primed roads depending on location, AADT and volume of truck traffic. Most surface treatment on secondary highways is constructed using High Float emulsion (100S, 150S or 250S, depending on traffic volume) and Class 2 aggregate (crusher-run) with 100% passing the 16.0 mm sieve, 25-50% passing the 4.75 mm sieve and 0-5% passing the 75 µm sieve. Emulsion quantities range from 1.20 to

1.50 kg/m^2 and aggregate quantities range from 16.5 to 19.0 kg/m^2. The Ministry is well satisfied with the performance of this type of surface treatment constructed on secondary highways using these materials.

Surface treatment is constructed occasionally using the closest available commercial source of Class 1 aggregates (6.7 mm to 9.5 mm in size) which are predominately limestone and wear and polish when subjected to higher traffic volumes. Also, there may be some penetration of the aggregate into the underlying surface contributing further to reducing anti-skid properties. Since it is not normal practice to first construct a levelling course on the existing surface, this type of surface treatment does not improve the riding qualities of the road and flushing occurs in the wheel tracks as the emulsion tends to flow to these areas. There is usually some loss of aggregate from high spots due to snow ploughing. In higher traffic volume areas, occasional construction and curing problems have caused some minor inconvenience to the travelling public. The Ministry therefore is not considering expanding the use of Class 1 surface treatment but will continue its use on a very limited basis on the more rural highways. The need therefore exists for a surface treatment system capable of providing a long wearing surface with good anti-skid properties that will withstand high traffic volumes.

Description of Previous Trial

With the above background, it was decided in 1980 to construct a trial section of surface treatment over a hot mix pavement using a larger aggregate, 10-13 mm in size[1]. The purpose of this trial was to determine if the larger aggregate could be successfully placed and would indeed result in a high quality surface treatment which would provide an extended service life for heavier traffic volumes. The trial was carried out on Highway 121 in July 1980. The existing pavement was an HL-4 hot mix constructed in 1974. On the basis of inspections in 1981 and 1982, it was observed that this surface treatment is performing very well. The larger aggregate, as anticipated, has

(1) Surface treatment with 10-13 mm aggregate, MTC Materials Information No. 29, by R.C. Aquin.

produced a more open textured surface than normally obtained using Class 1 aggregate. It was also noted after the first winter that snow ploughs have done minor damage by shearing some of the aggregate from the high spots on the road. It has been concluded that this condition may be overcome by constructing a closer textured surface.

Description of Modified Single Surface Treatment Trial

With the above in mind, a trial was arranged in 1982 using a modified single surface treatment system similar to that used in Sweden. This sytem consists of spraying one application of emulsified asphalt followed by two applications of aggregate. The first application is 12-16 mm aggregate and the second application is 4-8 mm aggregate. The 4 mm gap (8-12) between aggregate sizes is desirable for best results. Both aggregate applications are spread before rolling which is carried out using a vibratory roller equipped with a 40 mm thickness of rubber vulcanized onto the vibrating steel drum. This roller is especially manufactured for surface treatment work to vibrate the aggregate quickly into place without crushing, to provide good orientation and bonding of the aggregate, thus greatley reducing the possibility of loose aggregate which would inconvenience the travelling public.

Trial Location

The trial was constructed on Region Road No. 4 in the Region of Hamilton-Wentworth. Prior to 1976, Road No. 4 had been a surface treated surface. In view of increased traffic volume, the road was surfaced with a levelling course of HL-2 followed by 63 mm of HL-3 in the summer of 1976. The surface was in good condition with a minimum amount of cracking and was smooth and slightly porous. The riding qualities were excellent and wheel lane depression virtually non existent and no levelling was required. The road required only minor spray patching along the edges in isolated locations prior to constructing the trial surface treatment. The road is classified as Class A (an unrestricted hard surfaced road) and the last traffic count which was taken in 1978 was 2,030 AADT.

FIGURE 1: REGIONAL ROAD NO. 4
BEFORE SURFACE TREATMENT

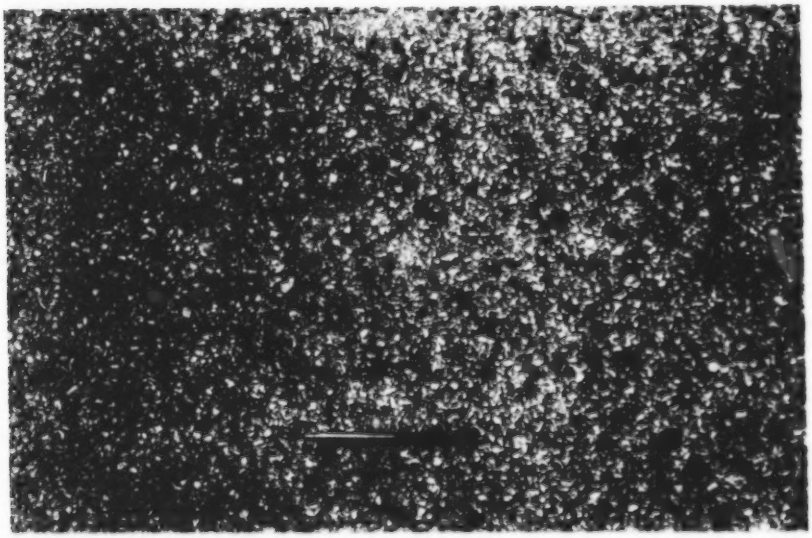


FIGURE 2: CLOSE-UP OF THE HOT MIX SURFACE
BEFORE SURFACE TREATMENT

MATERIALS

Aggregate

Steel slag was selected on the basis of having the most desirable physical characteristics for the trial. This was based on the premise that it should provide a longer wearing surface with excellent frictional characteristics due to its harsh macrotexture. The aggregate was obtained from Steetley Industries Ltd. in Dundas, Ontario, who have provided steel slag aggregate to the Ministry for use in Open and Dense Friction Course and HL-1 hot mix asphaltic concrete over the last five years.

Steetley Industries are a major supplier of quarried limestone aggregates in Southern Ontario. They purchase raw open hearth and basic oxygen furnace steel slag from Stelco Industries in Hamilton and process it at their quarry in Dundas.

On the basis of information obtained from Sweden, the Ministry requested Steetley Industries to produce two sizes of aggregate, namely 4-8 mm and 12-16 mm with a 4 mm gap for the trial. Processing consisted of washing and screening the raw slag in order to obtain material as close as possible to the desired gradation. The composition of the raw slag and the screen sizes used produced aggregates within the 4-9 mm and 12-19 mm ranges (larger than requested), with a gap of only 3 mm. Eighty percent of the 4-9 mm aggregate had a median size of 5.5 mm and ninety-three percent of the 12-19 mm aggregate had a median size of 13 mm. The median size of the smaller aggregate was 42% of the larger aggregate and considered acceptable since it has been observed that the most desirable surface texture is attained when the median size of the smaller aggregate is approximately 50% of the larger aggregate. The median size was obtained by drawing a line vertically upward to the millimetre (mm) scale from the intersection of the gradation line and the 50% passing line (see Figure A1), Appendix A.

For gradations of the aggregates and physical test results see Appendix A.

FIGURE 3: STEEL SLAG, 12-19 mm

FIGURE 4: STEEL SLAG, 4-9 mm

Asphalt Binder

CRS-2 emulsified asphalt was selected as the most suitable binder for the aggregate based on laboratory curing test results using RS-2, CRS-2 and HF-100S, shown in Appendix B, and confirmed by field test results shown in Appendix C.

CRS-2 was chosen because of its faster curing and bonding properties which would allow traffic to be restored as quickly as possible after construction with a minimum of disruption to the travelling public. It was also selected on the basis of having a higher viscosity to minimize the possibility of run-off when spraying the larger than usual amount of binder required by the system. The CRS-2 was obtained from T.J. Pounder Ltd., Brampton, Ontario, who had the contract to supply Hamilton-Wentworth Region with their annual emulsion requirements. For CRS-2 laboratory test results, see Appendix D.

Application Rates

The application rates which have been used successfully in Sweden under similar conditions are as follows:

Emulsified Asphalt	-	2.15 kg/m^2
12-16 mm Aggregate	-	20.5 kg/m^2
4-8 mm Aggregate	-	7.0 kg/m^2

For the laboratory trials, based on the porosity and absorptive properties of the steel slag and a comparison of the density of steel slag vs. limestone and an assessment of the pavement condition and traffic volume, it was decided that the most desirable laboratory application rates for emulsion and aggregate would be:

Emulsified Asphalt	-	2.50 kg/m^2
12-19 mm Aggregate	-	22.0 kg/m^2
4-9 mm Aggregate	-	9.0 kg/m^2

These rates were confirmed by field test results shown in Appendix C.

CONSTRUCTION

The work was carried out by the Region of Hamilton-Wentworth personnel and equipment with the addition of the vibratory roller and a second aggregate spreader. The Region has been constructing all of its own surface treatment work for many years and enjoys an excellent reputation for doing high quality work, which is evident from the results achieved on this trial.

Prior to commencement of the work on Region Road No. 4, a small test area 100 m in length was constructed on the Millgrove Sideroad adjoining Road No. 4. The purpose of this test was to familiarize Region personnel with the system, which departs from normal surface treatment practice since only one application of emulsion is sprayed with two applications of aggregate being spread before rolling. It provided an opportunity to calibrate the pressure distributors and aggregate spreaders as well as check the proposed design quantities and provided the roller operator with an opportunity to familiarize himself with the operation of the new vibratory roller.

On the basis of the results of this small test area, the desired application rates were revised as follows:

Emulsified Asphalt - 2.55 kg/m^2
12-19 mm Aggregate - 21.5 kg/m^2
4-9 mm Aggregate - 10.5 kg/m^2

Equipment

The following equipment was used to construct the work:

2 - Etnyre 1000 gallon capacity pressure distributors,
2 - Self-propelled Flaherty aggregate spreaders,
1 - Dynapac vibratory CA-25 10.0 tonne roller,
1 - Bros 9 wheel self-propelled 8.0 tonne roller,
1 - power broom,
7 - dump trucks.

Procedure, Modified Single Surface Treatment

The day prior to the start of the work, the pavement was swept clean with a power broom. The work started on August 24 at 10:45 a.m. The weather was ideal, with low humidity and bright and sunny conditions with a temperature of 22°C and northwest winds at 30-50 km/h.

The work proceeded as follows:

(1) The emulsion was sprayed at a temperature of 65°C.

(2) The 12-19 mm aggregate was spread immediately after the emulsion had been sprayed so that the distance between the pressure distributor and the aggregate spreader was at no time greater than 30 m.

(3) The 4-9 mm aggregate was then spread on top of the 12-19 mm so that the distance between the two aggregate spreaders was at no time greater than 15 m.

(4) The aggregates were then immediately rolled with the Dynapac vibratory roller, followed by the rubber-tired roller. A minimum of two passes with each roller was requested and obtained.

No difficulties were encountered in the operation. Spraying of the emulsion, spreading of the two aggregates and rolling were all carried out with no problems and the work was done at a very productive rate. The application rates of all materials were checked on the job using 50 cm square cardboard trays and a portable battery operated digital scale, as well as by totalling quantities used and calculating the area covered. The actual average application rates for the 3.22 km completed were as follows:

Emulsified Asphalt - 2.60 kg/m^2
12-19 mm Aggregate - 20.6 kg/m^2
4-9 mm Aggregate - 9.1 kg/m^2

FIGURE 5: SPRAYING BINDER

FIGURE 6: SPREADING 12-19 mm AGGREGATE

FIGURE 7: SPREADING 4-9 mm AGGREGATE

FIGURE 8: VIBRATORY ROLLER

FIGURE 9: RUBBER-TIRED ROLLER

Field sampling to determine the amount of emulsion and aggregate applied to the road was carried out as described and shown in Appendix E.

Field sampling to determine the viscosity of the emulsion just prior to spraying was carried out using the Zahn cup as described in Appendix F, test results are shown in Table F-2.

Procedure, Double Surface Treatment

For comparison purposes, adjoining the south end of the trial of the modified surface treatment previously described, a double surface treatment was constructed, 1.15 km in length, using the same emulsion (CRS-2) and steel slag aggregates (12-19 mm and 4-9 mm). This work was also carried out on August 24 using the same personnel, equipment and techniques under the same weather conditions.

The average application rates were as follows:

1st	Application of Emulsified Asphalt	- 1.80 kg/m^2
	Application of 12-19 mm Aggregate	- 20.5 kg/m^2
2nd	Application of Emulsified Asphalt	- 1.52 kg/m^2
	Application of 4-9 mm Aggregate	- 16.5 kg/m^2

Traffic Control

The road was closed off to through traffic during construction and only local traffic was allowed. The decision to close the road was made by the Region as a matter of convenience only. Traffic over both the modified single surface treatment and the double surface treatment could easily have been controlled in the normal manner using convoy trucks with the appropriate signs.

Rotary Power Brooming

Both sections were swept using a rotary power broom the following day to remove any loose aggregate.

COSTS

Modified Single Surface Treatment

The total cost per km for this modified surface treatment system was as follows:

Actual Material Costs

Emulsified Asphalt 17,483 kg @ $0.22	= $3.846.26	
Steel Slag Aggregate 202 tonnes @ $16.75	= 3,383.50	$ 7,229.76

*Estimated Application Costs

Applying Emulsified Asphalt 17,483 kg @ $0.056	=	979.05
Applying Steel Slag Aggregate 202 tonnes @ $10.00	= $2,020.00	2,999.05
Total Cost per km		$10,228.81

*The actual application costs incurred by the Region may not be representative of tendered costs for this work. Therefore, the application costs shown are based on current industry tendered costs for 1982, including allowances for supplying the additional chip spreader and the vibratory roller.

Double Surface Treatment

Total cost per km for this double surface treatment was as follows:

Actual Material Costs

Emulsified Asphalt 22,244 kg @ $0.22	= $4,893.68	
Steel Slag Aggregate 248 tonnes @ $16.75	= 4,154.00	$ 9,047.68

Estimated Application Costs

Applying Emulsified Asphalt 22,244 kg @ $0.056	= $1,245.66	
Applying Steel Slag Aggregate 248 tonnes @ $10.00	= 2,480.00	3,725.66
Total Cost per km		$12,773.34

COST COMPARISON SURFACE TREATMENT VS. HOT MIX

The average cost of hot mix resurfacing is estimated to be $23,040/km.

This is based on a 40 mm thickness of hot mix at	-	$ 21,740/km
Plus the necessary shouldering at	-	1,300/km
For a total of	-	$ 23,040/km

Therefore, the anticipated cost saving per km by replacing hot mix with surface treatment is as follows:

For replacing with modified single surface treatment:

Cost hot mix resurfacing	-	$ 23,040/km
Cost modified single surface treatment	-	10,228/km
Anticipated cost saving		$ 12,812/km

For replacing with double surface treatment:

Cost of hot mix resurfacing	-	$ 23,040/km
Cost of double surface treatment	-	12,773/km
Anticipated cost saving		$ 10,267/km

COMPARISON OF PAVEMENT SURFACE CHARACTERISTICS

The location of the trial of the modified single surface treatment process with steel slag on Region Road No. 4 provided a unique opportunity to directly compare this work with the existing HL-3 pavement, the newly constructed double surface treatment with steel slag and with a normal single surface treatment constructed with CRS-1 emulsion and Class 1 limestone aggregate on adjoining Region Road No. 21 and a newly constructed HL-1 pavement on King's Hwy. #5 using steel slag coarse aggregate.

Skid Resistance

Skid measurements were taken by the Pavement and Foundation Design Section using the Ontario Ministry of Transportation and Communications brake-force trailer conforming to ASTM Standard E-274. Results of the tests conducted at 80 km/h are shown in Appendix G and are summarized in Table A.

TABLE A

SKID RESISTANCE TEST RESULTS

Location	Type of Pavement	Year Constructed	SN 80 km/h (Range)
Region Road No. 4 Hamilton-Wentworth	Modified Single Surface Treatment with Steel Slag	1982	48.6
"	Double Surface Treatment With Steel Slag	1982	47.1
"	HL-3 Surface Course With Limestone Coarse Aggregate	1976	25.7
Region Road No. 21 Hamilton-Wentworth	Standard Single Surface Treatment with Quarried Limestone Chips (9 mm)	1982	43.2
King's Hwy. #5	HL-1 Surface Course With Slag Coarse Aggregate	1982	34.2

The above data indicates that surface treatments have superior skid resistance when compared to hot mix in the initial stage of their life.

The surface treatment constructed with steel slag aggregate shows a level of skid resistance values very satisfactory for all highways. The main component of the skid resistance is the very high density of macro projections of the steel slag surface.

It is anticipated that skid resistance values of the slag surface treatments will remain very high over an extended period, and that skid resistance values of the limestone surface treatment on Region Road No. 21 will be reduced over a relatively short period.

Noise Level

Noise level measurements were taken by the Research and Development Branch using the equipment outlined in Appendix H and the procedure outlined in Appendix I and are summarized in Table B.

TABLE B

Increase in Sound Levels Due to the Change from Typical Hot Mix HL-3 to Surface Treatment, Slag	Traffic Condition
5 dBA[1)]	Average operating speed of cars as well as trucks, 80 to 100 km/h, 10 to 20% of trucks
7 dBA[1)]	Cars only at 80 to 100 km/h
2 dBA[2)]	Average operating speed of cars 70-80 km/h, trucks 60 to 70 km/h 10% medium trucks, 10% heavy trucks
5 dBA[2)]	Cars only at 70 to 80 km/h

Notes: 1) Increase based on speed, traffic composition and previous experience.

2) Actually measured values at Region Road No. 4.

Sound levels are for receivers 15 m from the road. According to Table B, the increase in sound levels associated with surface treatment depends on traffic flow, speed and composition. For example, while sound levels of passenger cars travelling at 80 km/h can increase by about 7 dBA, the sound levels of heavy trucks travelling at speeds lower than 60 km/h may be virtually unchanged.

Texture Depth

Surface texture measurements were taken by the Bituminous Section using the sand patch method as described in Appendix J (reference ASTM STP-763). Results of these tests are shown in Appendix K and are summarized in Table D.

TABLE D

TEXTURE DEPTH TEST RESULTS

Location	Type of Pavement	Year Constructed	Texture Depth mm
Region Road No. 4 Hamilton-Wentworth	Modified Single Surface Treatment with Steel Slag	1982	4.43
"	Double Surface Treatment With Steel Slag	1982	3.25
"	HL-3 Surface Course With Limestone Coarse Aggregate	1976	0.67
Region Road No. 21 Hamilton-Wentworth	Standard Single Surface Treatment with Quarried Limestone Chips (9 mm)	1982	3.30

The results in Table D show that there is major difference in surface texture between roads surface treated with steel slag vs. hot mix.

This difference is primarily reponsible for the increase in noise level and skid resistance provided by the steel slag surface.

On high speed roads it has been found necessary to maintain a minimum texture depth of 0.65 mm to ensure that the decrease in skid resistance with speed is not unduly large.

The maintenance of surface texture depth on surface treated roads depends on traffic volume, the relative hardness of the old road surface, which will effect the embedment of the aggregate under traffic, and the wear of the aggregate. These changes can therefore have a marked effect on the performance of surface treatments and will directly effect not only surface texture but also noise level and skid resistance.

It is therefore planned to take skid resistance, noise level and texture depth measurements at yearly intervals for comparison purposes.

CONCLUSIONS

(1) This modified single surface treatment system can be constructed using standard surface treatment equipment with the addition of the vibratory roller and using standard construction methods without any unusual problems.

(2) This system can be constructed with much less inconvenience to the travelling public than normal single surface treatment.

(3) This system enjoys a cost saving of 56% over 40 mm of hot mix resurfacing.

(4) The excellent friction properties of the system compared to standard hot mix will improve the safety characteristics of pavements.

(5) The surface texture of the system results in a higher noise level than standard hot mix pavements.

RECOMMENDATIONS

Based on the outcome of further evaluation of this trial in the summer of 1983, consideration should be given to constructing a full scale project using this modified surface treatment system with steel slag in lieu of a 40 mm thickness of hot mix resurfacing. Also consideration should be given to using the system in black spot treatment.

In order to reduce the noise level and provide a slightly tighter surface texture without reducing frictional characteristics or service life, for future work it is recommended that the steel slag aggregate sizes be revised to 12-15 mm and 4-8 mm.

ACKNOWLEDGEMENTS

A special thanks to Mr. R. Fraser, Maintenance Engineer, Region of Hamilton-Wentworth, and to all the members of his office and field staff who made such a valuable contribution to this trial. The splendid co-operation provided by Mr. J. Marcolin and Mr. H. Donnelly of the Hamilton District Office, and Mr. R. W. Pipe and Mr. J. L. MacDonald of Steetley Industries, and Mr. E. McKillen of Dynapac Ltd., and Mr. M. Kavanaugh of T. J. Pounder Ltd. is much appreciated.

APPENDIX A - AGGREGATE GRADINGS AND PHYSICAL TEST RESULTS

TABLE A-1: 4-9 AND 12-19 mm AGGREGATE GRADINGS

MTC Sieve mm	Percentage Passing	
	4-9 mm	12-19 mm
19.0	-	100.00
16.0	-	96.3
13.2	-	63.4
9.5	100.0	4.0
6.7	68.4	2.6
4.75	20.6	2.3
2.36	2.3	-
1.18	1.7	-
0.60	1.3	-
0.30	1.0	-
0.15	0.7	-
0.075	0.3[1]	1.0[1]

1. Wash pass 75 µm sieve, MTC LS-601 Test Method

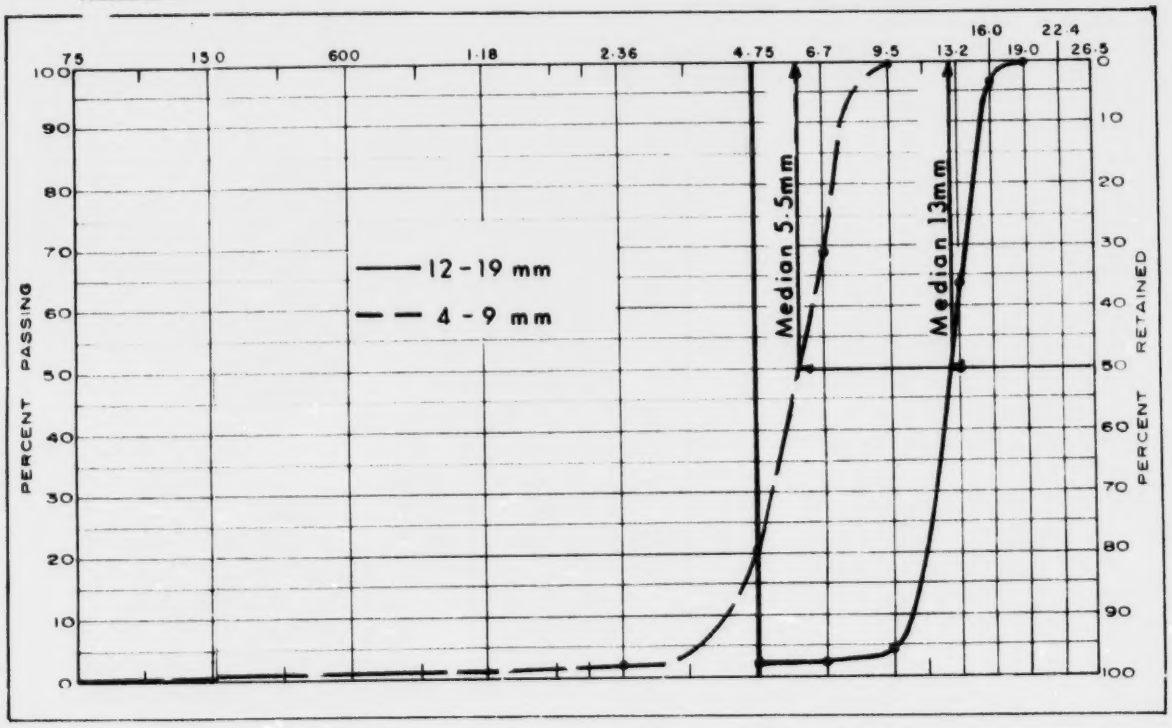
TABLE A-2: PHYSICAL TEST RESULTS

Test	4-9 mm	12-19 mm
Los Angeles Abrasion Loss, %	24.64	23.70
Absorption, %	1.819	1.235
Non-Slag Material, %	9.5	3.8
Aggregate Abrasion Value (AAV)[1]	-	3.8
Polished Stone Value (PSV)[2]	58.5	60.0
Relative Density	3.406	3.555
Density, Loose, t/m^3	1.635	1.625

1. British Standard BS 812, 1975.
   The resistance of aggregate particles to wear is measured by the AAV test. A low value indicates a high resistance to wear. A typical limestone has a AAV range of 8-30.

2. British Standard BS 812, 1975.
   An aggregate with a high PSV may be thought of as having good (skid) resistance to the action of polishing by vehicle tires. The higher the PSV the better the aggregate. A typical limestone has a PSV range of 30-50.

FIGURE A-1: 4-9 AND 12-19 mm AGGREGATE GRADINGS



APPENDIX B - LABORATORY PROCEDURE FOR SELECTING THE MOST SUITABLE TYPE AND GRADE OF EMULSIFIED ASPHALT FOR A GIVEN AGGREGATE FOR SURFACE TREATMENT

(1) Calculate the weight in grams of aggregate and emulsion required for a 22.8 cm x 33.0 cm pan based on the design quantities. (Design quantities in grams per square metre ÷ 13.28).

(2) Weigh calculated weight (1) of dried aggregate at 25°C into a metal container.

(3) Add 2% moisture by mass of cold tap water to the aggregate. Mix thoroughly and let stand one hour.

(4) Heat the emulsion to 70°C and pour the desired amount evenly into the pan.

(5) Sprinkle onto the hot emulsion, the required amount of aggregate, as evenly as possible.

(6) Immediately roll the aggregate three times in the longitudinal direction with a steel roller 2.6 cm in width and 5.1 cm in diameter and weighing 1.8 kg. Roll with moderate hand pressure.

(7) Test for curing at room temperature, every 15 minutes. Use a 2.5 cm spatula to pick apart about a 5.1 cm square area of the sample. Note the colour of the emulsion, percent cured, and the bond strength of the aggregate to the emulsion.

(8) Continue to inspect until the sample is 100% cured and a firm bond is obtained.

This test should be carried out with anionic, cationic and high float emulsion to select the most suitable emulsion for the aggregate.

Interpretation of Results

The emulsion with the fastest curing time and the best bond should be selected for the aggregate.

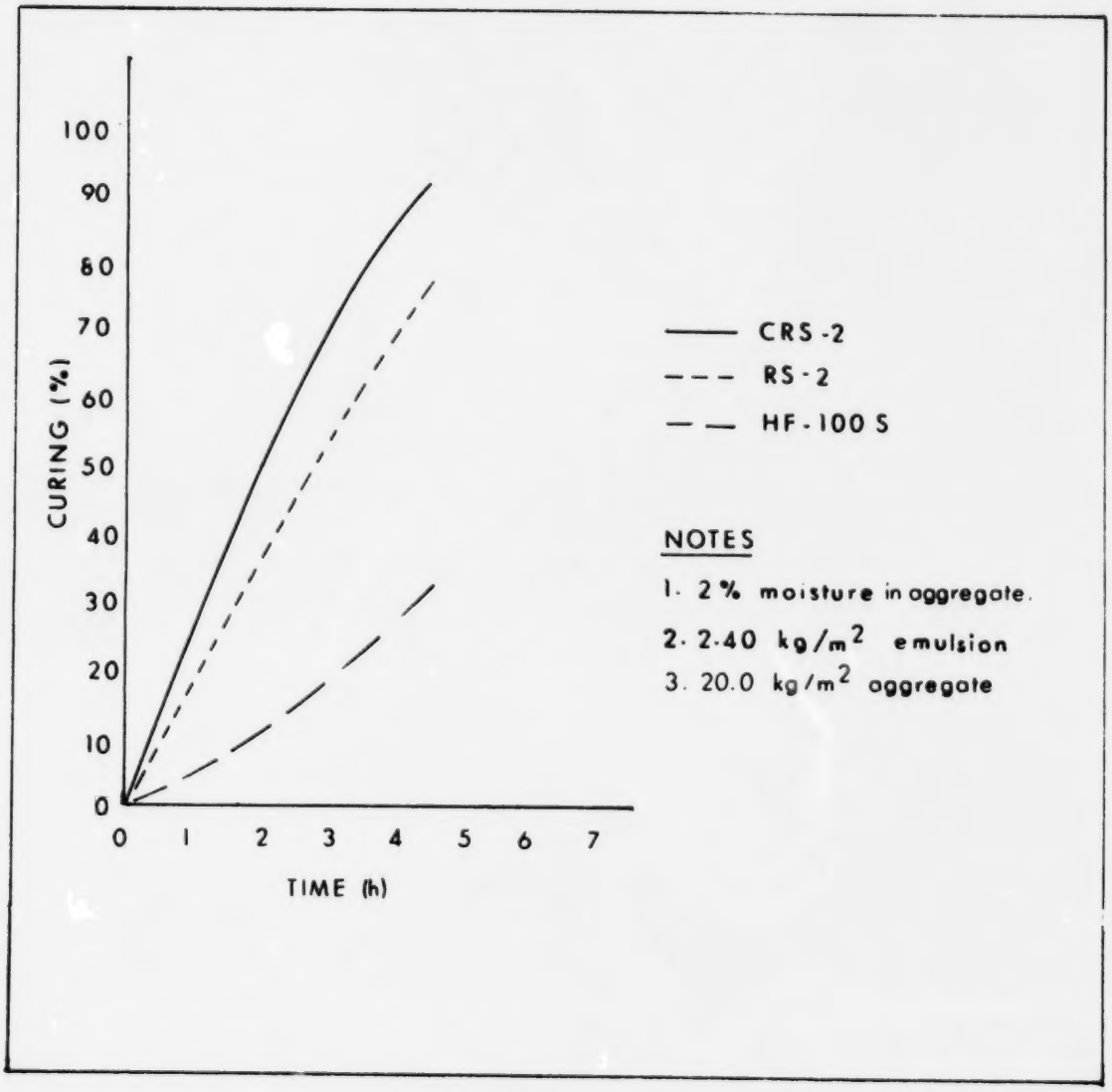


FIGURE B-1: CURING TESTS WITH 12-19 mm STEEL SLAG

APPENDIX C - FIELD TESTS TO CONFIRM EMULSION-SLAG COMPATIBILITY

Test Patches with Steel Slag

Six test patches with emulsion and steel slag were placed in the MTC Parking lot "C" on 82-06-09, and application rates of the patches are shown below. The purposes of the tests were to:

(1) determine approximate application rates of emulsion and aggregate.

(2) determine the most suitable emulsion to use with steel slag.

(3) observe performance over a two-month period.

Aggregates

Two gradations of steel slag were used:

4-9 mm, and 12-19 mm

Tap water at 2% was added to the 4-9 and 12-19 mm aggregate.

Procedure

(1) Aggregates were weighed and water was added.

(2) Emulsions were weighed into beakers.

(3) Test site was swept clean with a broom.

(4) Emulsion was poured onto pavement into a template 30.5 cm x 30.5 cm square and spread with a spatula.

(5) Aggregate was immediately spread from a pan.

(6) Aggregate was rolled immediately with six complete coverages of a car tire.

(7) Traffic was kept off patches for 18 hours.

Weather

25°C, sunny, light breeze

APPLICATION RATES

Modified Single Surface Treatment

2.50 kg/m^2
12-19 mm @ 22.0 kg/m^2
4-9 mm @ 9.0 kg/m^2
3 patches 30.5 x 30.5 cm with CRS-2, RS-2 and HF-100S

Double Surface Treatment

1.80 kg/m^2
12-19 mm @ 21.0 kg/m^2

1.45 kg/m^2
4-9 mm @ 9.0 kg/m^2

3 patches 30.5 x 30.5 cm with CRS-2, RS-2 and HF-100S

APPENDIX C

Observations During Tests

1. The CRS-2 emulsion broke very quickly. The RS-2 was the second fastest breaking emulsion. The HF-100S was the slowest breaking. Patches with the HF-100S were still tender after four hours.

2. The application rates of aggregate were reasonably correct.

3. The CRS-2 emulsion was very viscous, followed by the RS-2 and the HF-100S.

4. Where HF-100S was used as binder, there was pick-up while rolling.

5. The method of applying emulsion (pouring emulsion from a beaker), for the second application on the conventional double was not satisfactory. The emulsion could not be uniformly spread.

6. On patches of double surface treatment, all loose 12-19 mm aggregate was removed before applying second application of binder and 4-9 mm chips.

7. Compactive effort was not sufficient to key all the 4-9 mm aggregate into the binder in any of the patches.

Results of the test patches confirmed that the most suitable emulsion for the trial was CRS-2.

APPENDIX D - CRS-2 LABORATORY TEST RESULTS

TABLE D-1: CRS-2 LABORATORY TEST RESULTS

Test	CRS-2	MTC Requirements Min.	Max.
Visc. at 50°C, S.F.s	102.2	100	400
Residue	71.1	67	-
Residue Penetration	182	100	250
Residue Duct. at 25°C	60+	60	-
Settlement, 5 Days, %	1.1	-	5
Sieve Test, %	0.06	-	0.10
Demulsibility, %	41.5	40	-
Particle Charge	Positive	Positive	
Oil Portion, %	0.6	-	3

APPENDIX E - FIELD SAMPLING TO DETERMINE THE AMOUNT OF BINDER AND AGGREGATE APPLIED TO A ROAD

The following equipment is required:

(1) 1 - Battery operated digital scale, 10 kg capacity, with a stainless steel platform approximately 30 cm x 40 cm.

(2) A supply of cardboard trays 50 cm x 50 cm with a 2.5 cm lip.

(3) Pocket calculator.

(4) Carpenter's level.

(5) Gloves.

(6) Mineral spirits.

(7) Rags.

Procedure

(1) Set up and level digital scales.

(2) Number the cardboard trays.

(3) Obtain the tare weight in kilograms of two 50 x 50 cm cardboard trays and record.

(4) Place the two cardboard trays in the centre of the lane being treated approximately two feet apart and parallel to the centre-line of the road, immediately prior to the area being treated.

(5) Remove the first tray after the binder has been sprayed and before the aggregate has been applied.

(6) Remove the second tray after the binder has been sprayed and the aggregate has been applied and before rolling.

(7) Obtain the gross weight in kilograms of the first tray.

(8) Obtain the net weight in kilograms of binder applied in the first tray. Net Weight = Gross Weight - Tare Weight.

(9) Calculate the amount of binder applied to the road as follows:

Net Weight (8) x 4 = $\quad kg/m^2$

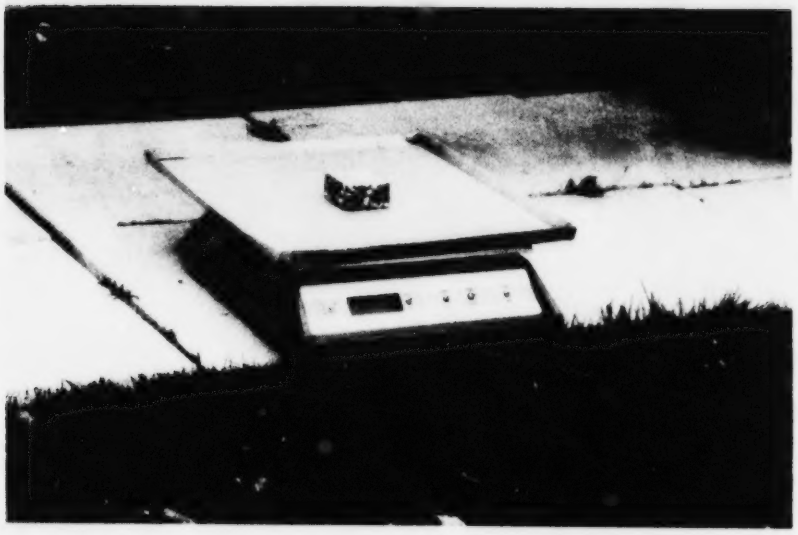


FIGURE E-1: WEIGHING TRAY

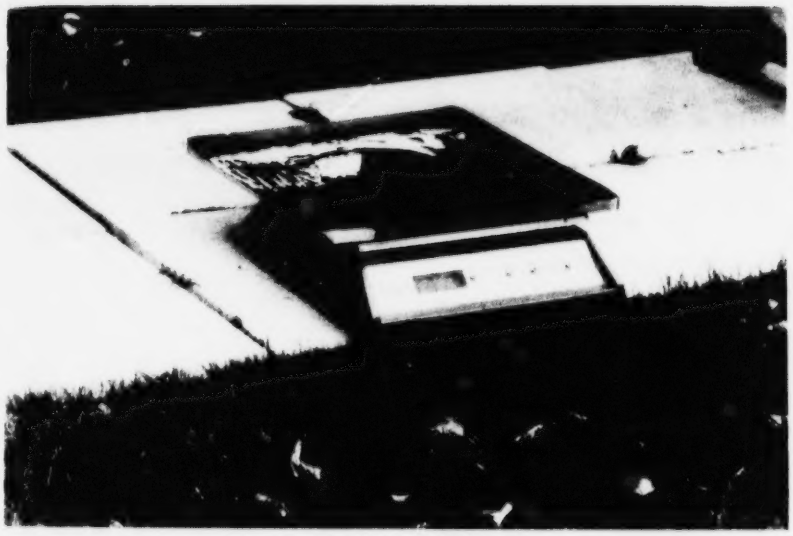


FIGURE E-2: WEIGHING TRAY AND BINDER

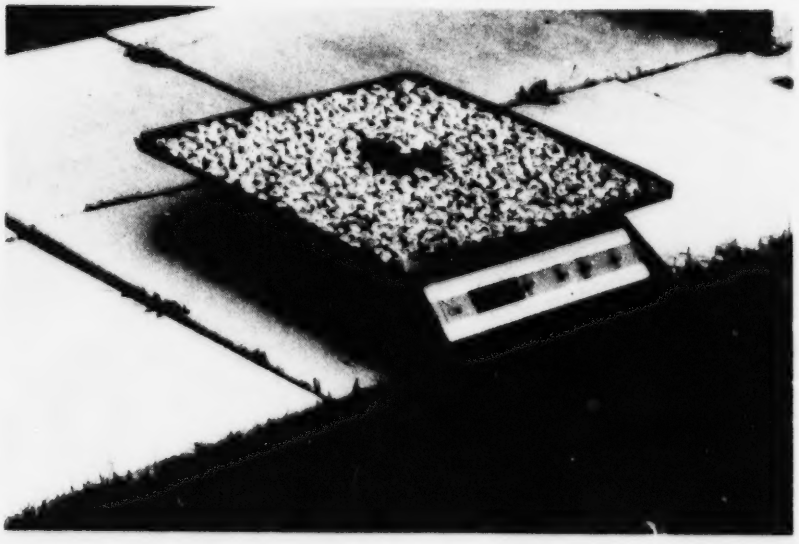


FIGURE E-3: WEIGHING TRAY, BINDER AND 12-19 mm AGGREGATE

(10) Obtain the gross weight in kilograms of the second tray.

(11) Obtain the net weight in kilograms of binder and aggregate applied in the second tray.

Net Weight = Gross Weight - Tare Weight

(12) Obtain the net weight in kilograms of aggregate applied in the second tray.

Net Weight of Aggregate
= Net Weight of second tray (11)
- Net Weight of first tray (8)

(13) Calculate the amount of aggregate applied to the road as follows:

Net Weight of Aggregate (12) x 4
= kg/m^2

(14) Repeat sampling process at least three times per 2.0 km lanes and adjust application rates if necessary to obtained desired quantities.

Maintenance

- recharge the batteries in the scale as required.
- clean scale platform with mineral spirits and rags after use.

APPENDIX F - FIELD TEST FOR DETERMINING THE VISCOSITY OF EMULSIFIED ASPHALT PRIOR TO SPRAYING

ZAHN VISCOSIMETER TEST FOR EMULSIFIED ASPHALT

Equipment

1. Zahn viscosimeter cup No. 3 (Figure F-1).
2. Stop watch.
3. Thermometer range 40°C-90°C.
4. Gallon sample cans.
5. Mineral spirits (varsol).
6. Rags.
7. Table I used to determine viscosity in Saybolt Furol seconds at 50°C for emulsified asphalt.

Procedure

1. Obtain emulsion sample in one gallon can.
2. Immediately take emulsion temperature and record.
3. Immerse Zahn cup into emulsion until the top of the cup is approximately 15 mm below emulsion surface. (Figure F-2).
4. Allow the cup to warm up (1-2 minutes).
5. Lift the cup until the rim of cup is just below the surface.
6. Lift the cup out of the emulsion and at the same time start the stop watch. (Figure F-3).
7. When the stream breaks, stop the stop watch. (Figure F-4).
8. Record the time in the nearest 1/10's.
9. Repeat the procedure three times taking the average time to the nearest second.
10. Record the average viscosity in Saybolt Furol seconds at 50°C as determined using Table F-1.

Note: 1. The test must be performed within the temperature range 60°C to 80°C. If the sample is above 80°C, it should be allowed to cool to less than 80°C before testing. If the emulsion as delivered is below 60°C, a decision has to be made either to reject the material because of low temperature or to heat the material on site above the minimum of 60°C before sampling and testing. Do not attempt to heat the sample.

2. One Zahn test (average of three readings) is required for each tanker load of emulsion.

3. The sample taken for Zahn testing can be used as the field sample submitted for laboratory results.

4. Some judgement is necessary when stopping the time. The stream becomes narrow and then breaks. Stop the time when the stream first breaks.

TABLE F-1

FOR DETERMINING VISCOSITY IN SAYBOLT FUROL SECONDS
AT 50°C FOR EMULSIFIED ASPHALT

Seconds for Flow Thru Zahn Cup No. 3 @ 60 to 80°C	Saybolt Furol Seconds @ 50°C	Seconds for Flow Thru Zahn Cup No. 3 @ 60 to 80°C	Saybolt Furol Seconds @ 50°C
5	12	31	90
6	15	32	93
7	18	33	96
8	21	34	99
9	24	35	102
10	27	36	105
11	30	37	108
12	33	38	112
13	36	39	115
14	39	40	118
15	42	41	121
16	45	42	124
17	48	43	127
18	51	44	130
19	54	45	133
20	57	46	136
21	60	47	139
22	63	48	142
23	66	49	145
24	69	50	148
25	72	51	151
26	75	52	154
27	78	53	157
28	81	54	160
29	84	55	163
30	87	56	166

TABLE F-2

VISCOSITY DETERMINED BY USING ZAHN CUP NO. 3

Sample No.	Temp. °C	Seconds for Flow Through Zahn Cup	Saybolt Furol Seconds @ 50°C
1	68	36	105
2	70	39	115
3	65	42	124

FIGURE F-1: ZAHN VISCOSIMETER
CUP NO. 3

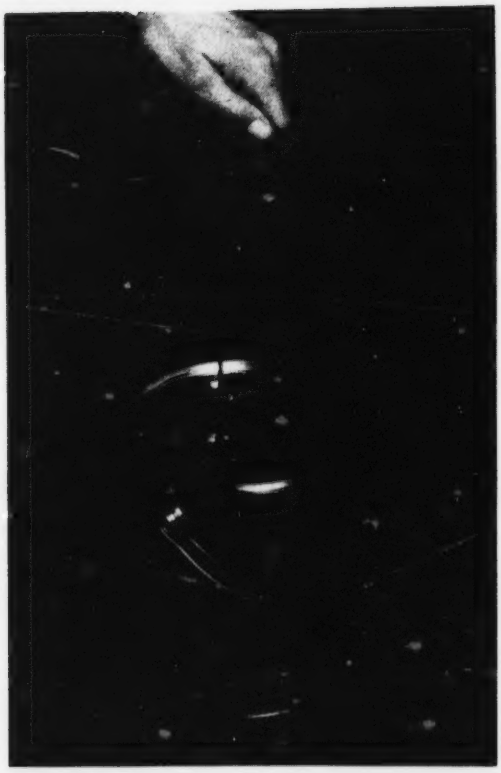


FIGURE F-2: CUP IMMERSED
IN BINDER

FIGURE F-3: LIFTING CUP
OUT OF BINDER

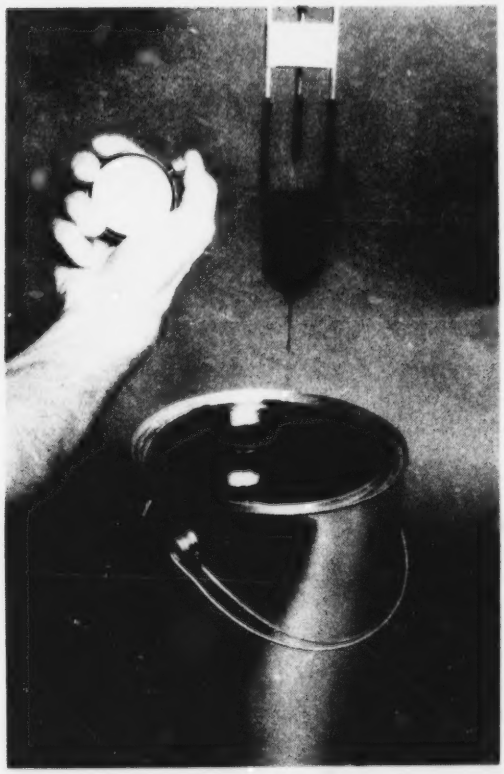


FIGURE F-4: STREAM BREAKS
AND TIME STOPPED

APPENDIX G

SKID RESISTANCE DATA

Hwy No. Hamilton-Wentworth Reg. 4

Location Sixth Concession to Hwy. 5

Date 82 10 06

Direction SOUTHBOUND

Lane No. Driving Lane

NORTH

OFFSET	SPEED	SN	INTERSECTION
0.00			Hwy. 5
1.10			Pavement Change
1.13	80.3	23.9	
1.28	80.2	23.5	SN80=25.7
1.48	79.7	30.6	
1.68	78.4	28.1	
1.82			Pavement Change
1.84	76.8	47.6	
2.07	77.6	45.7	
2.31			Fourth Concession
2.51	76.1	51.4	SN80=47.1
2.79	78.3	46.3	
2.99			Pavement Change
3.04	78.6	50.5	
3.44	77.4	48.4	
3.86	77.1	50.7	
4.27			Fifth Concession
4.39	77.2	46.4	SN80=48.6
4.99	75.9	47.7	
5.45	77.0	47.6	
5.84	78.6	50.1	
6.09	77.7	53.4	
6.19			Pavement Change
6.25	78.4	24.4	
6.51	78.2	25.6	SN80=25.8
6.82	80.2	27.9	
7.46	79.2	26.0	

SKID RESISTANCE DATA

Hwy No. Hamilton-Wentworth Reg. 4

Location Hwy. 5 to Sixth Concession

Date 82 10 06

Direction NORTHBOUND

Lane No. Driving Lane

NORTH

OFFSET	SPEED	SN	INTERSECTION
0.00			
1.10			Pavement Change
1.18	79.2	24.4	
1.32	78.0	27.9	SN80=26.0
1.53	80.6	24.4	
1.69	79.9	29.0	
1.82			Pavement Change
1.89	79.7	47.5	
2.11	81.1	43.6	
			SN80=46.6
2.56	80.0	46.9	
2.85	79.9	45.4	
2.99			Pavement Change
3.08	79.7	48.6	
3.48	79.4	49.3	
3.92	79.5	49.2	
4.27			Fifth Concession
4.42	78.9	47.4	
4.86	76.8	47.5	
5.05	78.3	48.1	SN80=48.5
5.50	80.3	47.6	
5.88	79.1	49.2	
6.12	77.4	49.6	
6.19			Pavement Change

SKID RESISTANCE DATA

Hwy No. Hamilton-Wentworth Reg. 21

Location Reg. 4 to Hwy. 6

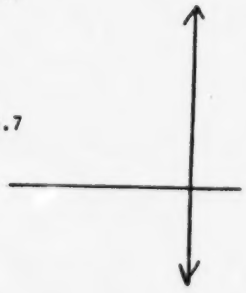
Date 82 10 06

Direction EASTBOUND

Lane No. Driving Lane

EAST

OFFSET	SPEED	SN	INTERSECTION
0.00			Reg. 4
0.48	75.6	47.6	
1.39	76.2	46.6	SN80=45.7
2.12	80.5	45.8	
2.68	77.5	45.7	
3.53	78.3	43.0	SN80=41.8
4.14	79.2	42.1	
4.38	78.2	42.2	
4.42			"60 km/hr."
	OVERALL SN80=43.2		
5.37			Hwy. 6



SKID RESISTANCE DATA

Hwy No. Hamilton-Wentworth Reg. 21

Location Hwy. 6 to Reg. 4

Date 82 10 06

Direction WESTBOUND

Lane No. Driving Lane

EAST

OFFSET	SPEED	SN	INTERSECTION
0.00			Reg. 4
0.22	77.5	50.5	
0.42	79.2	47.1	
0.60	84.1	48.4	
1.36	78.4	50.0	
2.07	79.7	47.9	
2.60	79.1	49.3	
2.83	76.5	48.1	
3.49	79.2	46.6	
4.05	79.0	47.7	
4.42			"60 km/hr."
	OVERALL SN80=48.3		
5.37			Hwy. 6

SKID RESISTANCE DATA

Hwy No. 5

Location Hamilton - Hwy. 6 to Halton Reg. 4

Date 82 10 06 **Direction** WESTBOUND

Lane No. Driving Lane

EAST ↓

OFFSET	SPEED	SN	INTERSECTION
0.00			Reg. 4
0.15			Pavement Change
0.27			Moxley Rd.
0.55	78.3	34.4	
0.94	78.7	32.9	
1.69			Ofield Rd. S
1.89			Ofield Rd. N
1.97	78.2	33.8	
2.92	78.8	34.9	
3.16			Mazza Ave.
3.95	76.1	37.1	
4.12			Sydenham
4.32			Millgrove Sideroad
4.95	77.0	33.9	
5.33			Rock Chapel Rd.
5.94	78.5	33.5	
6.32	77.6	33.0	
6.53			"80 km/hr."
	OVERALL SNBO=32.3		
7.14			Hwy. 6

APPENDIX G

SKID RESISTANCE DATA

Hwy No. 5

Location Hamilton - Halton Reg. 4 to Hwy. 6

Date 82 10 06

Direction EASTBOUND

Lane No. Driving Lane

EAST ↓

OFFSET	SPEED	SN	INTERSECTION
0.00			Reg. 4
0.15			Pavement Change
0.27			Moxley Rd.
0.41	79.6	37.6	
1.09	79.2	35.4	
1.69			Ofield Rd. S
1.89			Ofield Rd. N
2.14	80.4	36.3	
3.04	80.7	35.5	
3.16			Mazza Ave.
4.01	78.4	35.7	
4.12			Sydenham
4.32			Millgrove Sideroad
5.04	77.8	35.5	
5.33			Rock Chapel Rd.
5.96			Algonquin Ave.
6.09	75.2	36.8	
6.56			"60 km/hr."
6.66	74.4	37.3	
	OVERALL SN60=36.0		
7.14			Hwy. 6

FIGURE G-1: SKID TRAILER AND TRUCK

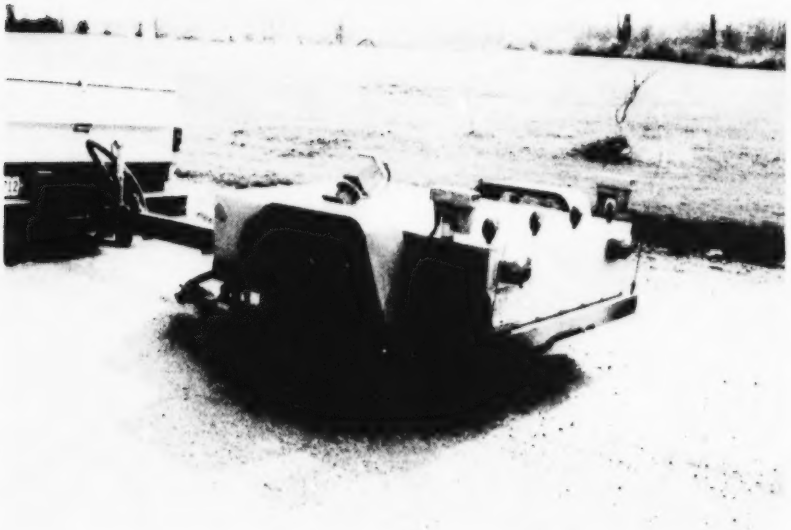


FIGURE G-2: SKID TRAILER

FIGURE G-3: PERFORMING SKID TEST

APPENDIX H - NOISE LEVEL MEASUREMENT EQUIPMENT

The following equipment was used to conduct measurements:

Bruel & Kjaer Piston Phone Calibrator, Type 4220
Bruel & Kjaer Integrating Sound Level Meter, Type 2218
Bruel & Kjaer 30 m Extension Cable, Type AO 0029
Uher 4200 Stereo Report Monitor Tape Recorder
BASF Recording Tape, Type DP 26, ferro LH, Hi Fi

Additional equipment required to analyze the results:

Bruel & Kjaer Noise Level Analyser, Type 4426
Bruel & Kjaer Alphanumeric Printer, Type 2312
Bruel & Kjaer Level Recorder, Type 2306
Bruel & Kjaer Digital Frequency Analyser, Type 2131
Hewlett Packard X-Y Recorder, Type 7035B

APPENDIX I - NOISE MEASUREMENT PROCEDURE

Two sound level meters were located at two adjacent pavement sections, 15 m from the roadway centreline. Sound level measurements at these two locations were done simultaneoulsy by recording sound levels on a magnetic tape for later analysis in the laboratory.

The first set of measurements recorded sound levels emitted by the total (normal) traffic flow passing by on the two adjacent pavement sections. Since both measurement locations were identical in terms of distance and traffic flow, any differences in the measured sound levels were attributed to the pavement/tire noise.

The second set of measurements recorded sound levels of a single vehicle (1980 Plymouth Horizon) passing at a constant speed of 80 km/h.

Frequency Spectra (See Appendix I)

One-third octave band frequency spectra of sound levels emitted by only passenger cars are compared in Figure I-1. According to Figure I-1, in addition to the overall differencd in decibel levels, the two pavements have also different frequency spectra. The surface treatment sound levels are about 5 to 12 dB higher in the frequency range of 315 to 1000 Hz than the corresponding sound levels obtained for HL-3 pavement. At higher frequencies, i.e. above approx. 1600 Hz, the sound levels of HL-3 pavement are higher by about 3 to 4 dB.

Figure I-2 results for 1980 Horizon are quite similar to those of Figure I-1. A notable feature of Figure I-2 is a rather pronounced frequency peak centred at 1000 Hz. This tonal characteristic is subdued in Figure I-1 which is an average result obtained for four passenger cars. Finally, Figure I-3 shows corresponding frequency spectra for the total traffic flow which included slow moving heavy trucks. The trucks may have masked the differences between the two pavements. (Sound levels of slow moving heavy trucks, with speed of less than approx. 70 km/h, are not influenced by pavement surface textures and may be loud enough to overshadow sound levels emitted by passenger cars.)

Overall Comparison

The orientation table below is based on the results measured on Region Road No. 4 and, particularly, on the results measured previously.

TABLE 1-1

CHANGE IN OVERALL SOUND LEVELS
DUE TO PAVEMENT TEXTURE, dBA

Pavement Surface Type	Traffic Flow Contains 10-20% of Trucks	
	Aver. Oper. Speed Abou 0 km/h	Aver. Oper. Speed About 80 km/h
Used P.C. Concrete, Good Structural Condition	-1	0
New P.C. Concrete,		
Wire Brushed	+6	+5
Grooved 1/	+5 to 8	+4 to 7
HL-1	0	0
HL-3	0	0
DFC	-1.5	-0.5
OFC	-2.5	-1.5
Surface Treatment	+5.0	+4.0

Note: 1/ e.g. Plastic grooving, type grooving or diamond grooving. Table should be used for orientation purposes only since not all pavements of the same pavement surface type are identical and may differ by 1 or 2 dBA (i.e. not all surface treatments are the same even though only one number is given).

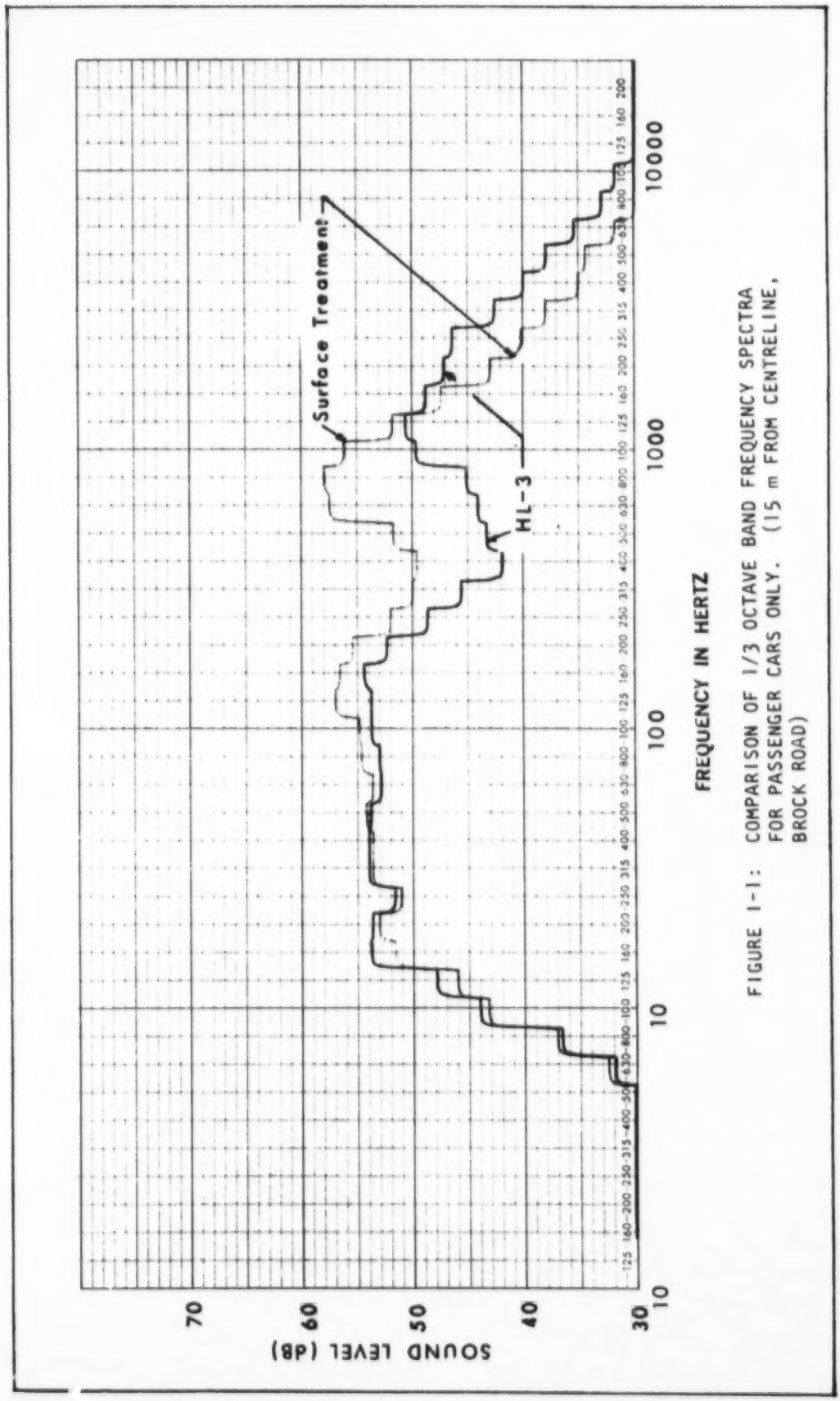


FIGURE 1-1: COMPARISON OF 1/3 OCTAVE BAND FREQUENCY SPECTRA FOR PASSENGER CARS ONLY. (15 m FROM CENTRELINE, BROCK ROAD)

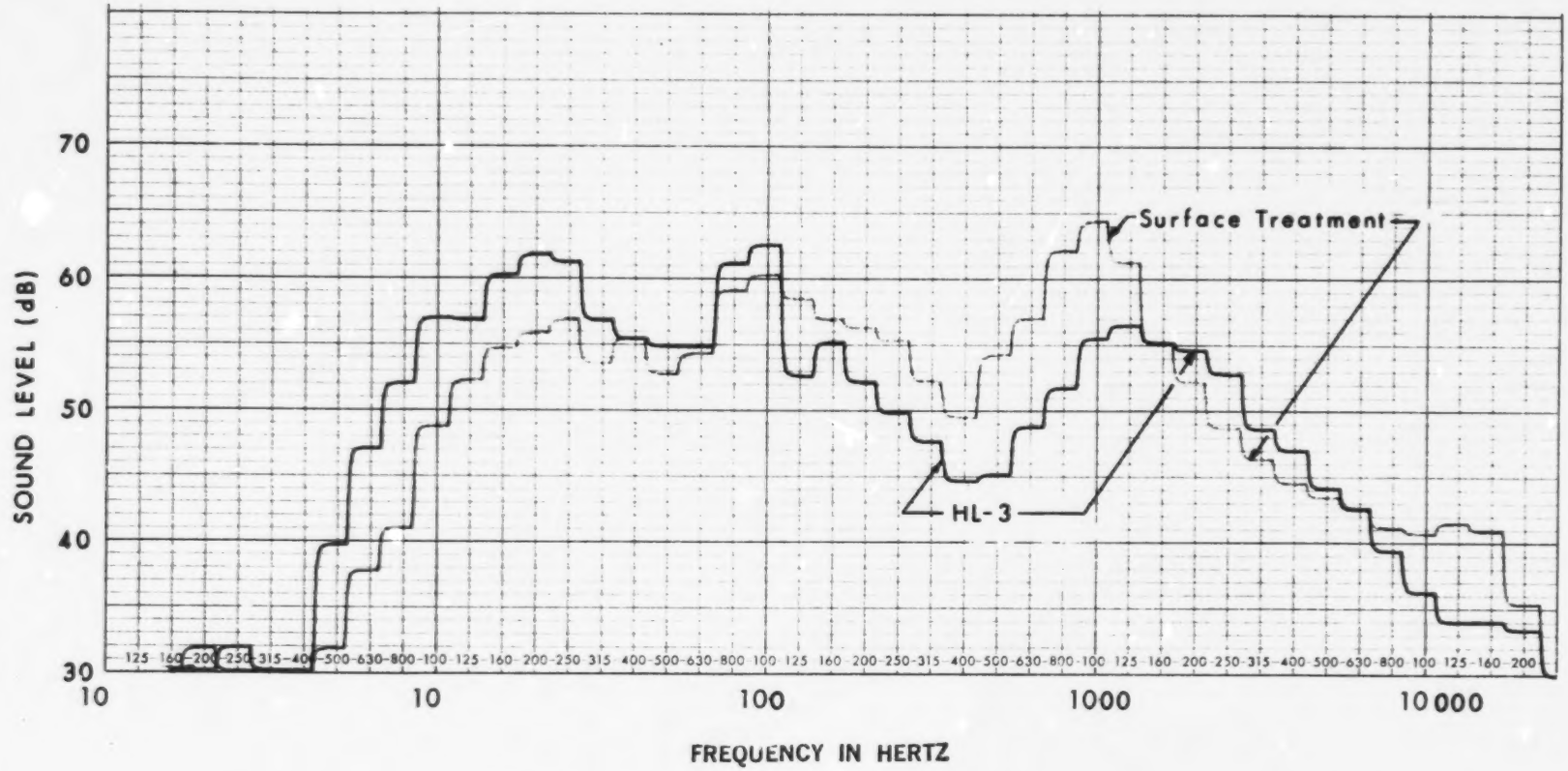


FIGURE I-2: COMPARISON OF 1/3 OCTAVE BAND FREQUENCY SPECTRA FOR 1980 HORIZON. (15 m FROM CENTRELINE, BROCK ROAD)

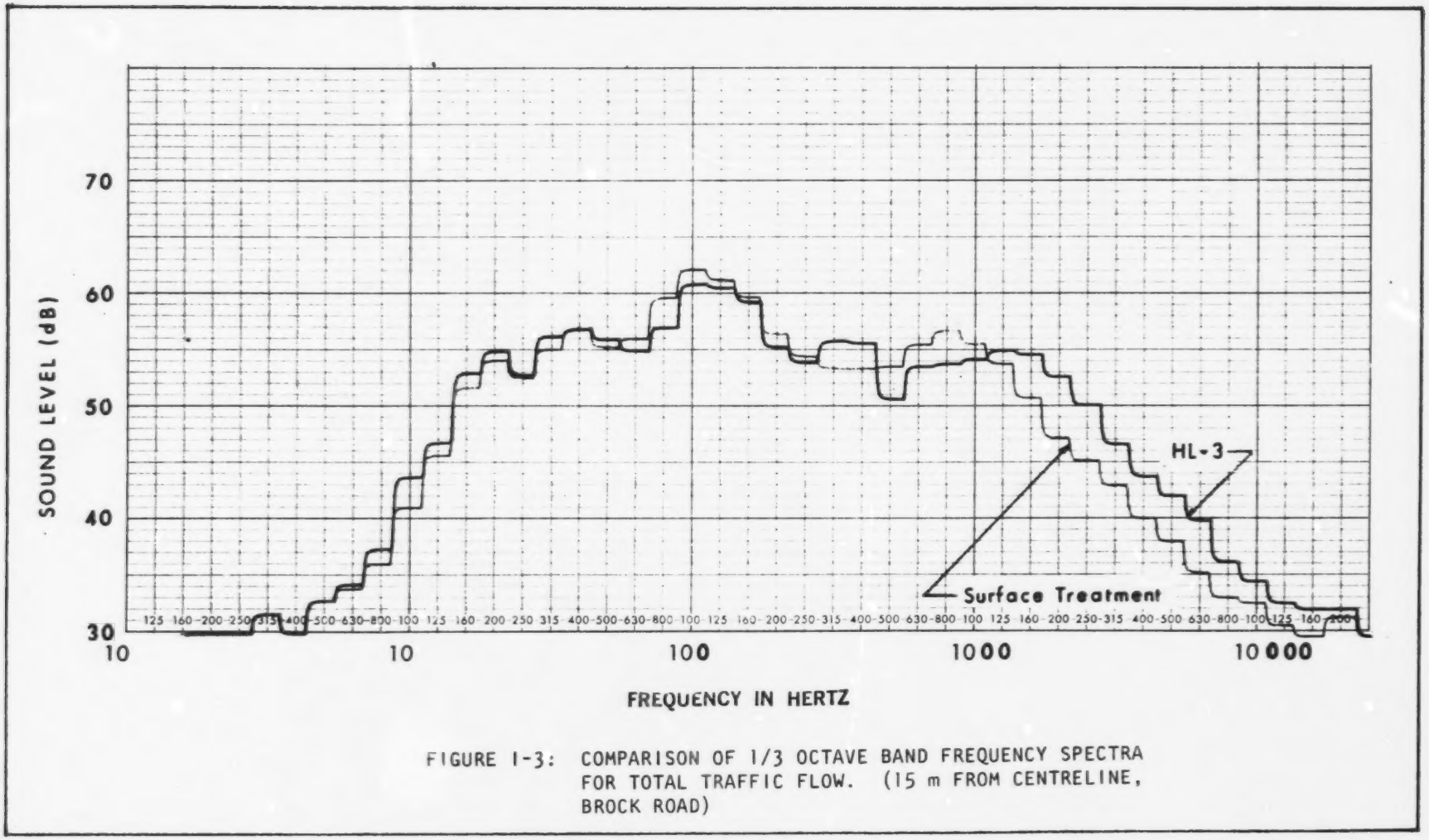


FIGURE I-3: COMPARISON OF 1/3 OCTAVE BAND FREQUENCY SPECTRA FOR TOTAL TRAFFIC FLOW. (15 m FROM CENTRELINE, BROCK ROAD)

APPENDIX J - MEASUREMENT OF TEXTURE DEPTH BY THE SAND PATCH METHOD

MATERIAL

Ottawa Sand C-109

APPARATUS

graduated cylinder, 250 mL
yellow crayon
broom
ruler, 40 cm
hard rubber disc, 7 cm diameter

PROCEDURE

1. Remove loose material from the surface with broom.
2. Draw a circle approximately 40 cm in diameter.
3. Measure approximately 500 mL of sand, tapping the graduated cylinder lightly on the road three times before reading the volume.
4. Pour the sand into the centre of the circle.
5. Spread the sand with the rubber disc, starting in the centre and gradually working outward using circular motions, keeping the sand patch as circular as possible.
6. Measure the diameter of the sand patch in four places.

CALCULATION

$$TD = \frac{V}{r^2}$$

where TD = texture depth (cm)
V = volume (mL) of sand
r = radius (cm)

1. Determine the average diameter and radius.
2. Determine the TD.

FREQUENCY

Every 0.5 km in the outside wheel passes.

APPENDIX J

Texture depth is the mean thickness of the layer of sand that fills the cavities and channels in the pavement surface if spread evenly on a smooth surface over a covered area.

Texture is the "roughness" that in a bituminous surface, is most significantly influenced by aggregate size. Texture generates resistance to sliding via the hysteresis effects in the tread rubber and facilitates the expulsion of water from the tire pavement interface.

The friction that develops between tire and pavement has two components, adhesion and hysteresis. (Adhesion is surface friction, hysteresis is deformation loss).

Microroughness (that roughness that is being diminished when the surface is being polished) influences the adhesion components most strongly. Macroroughness or texture (as given by the shape and arrangement of the aggregate particles embedded in the matrix of the pavement surface course) has a first-order effect on the hysteresis component.

The adhesion friction component on wet surface tends to decrease with speed, the hysteresis component gains in importance at higher speeds. Thus, texture is beneficial to the generation of friction, but its more important function is to provide channels by which water can escape from under the tire so that the tread rubber can make contact with the pavement.

Correlation of texture depth with skid resistance is not perfect, but adequate for many purposes.

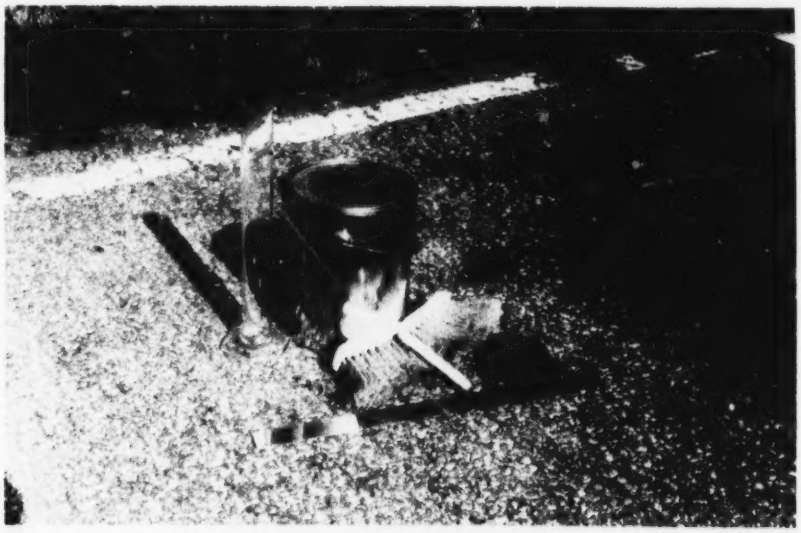


FIGURE J-1: SAND PATCH APPARATUS

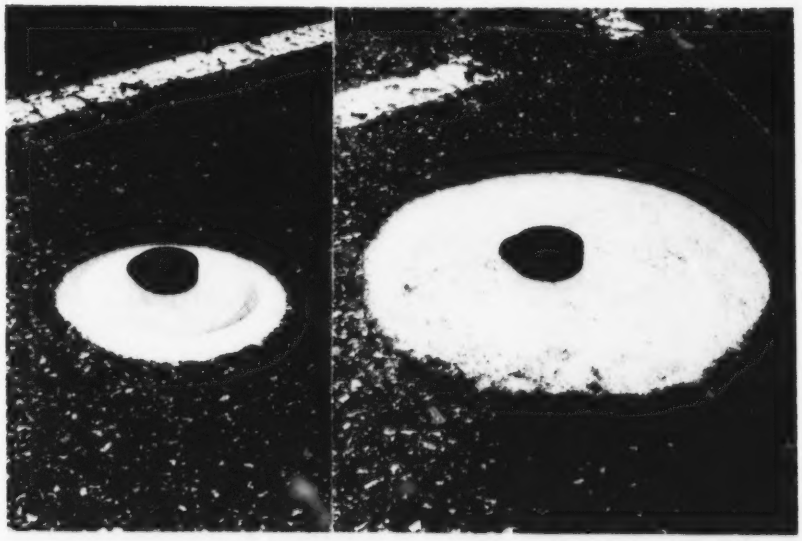


FIGURE J-2: SPREADING OTTAWA SAND

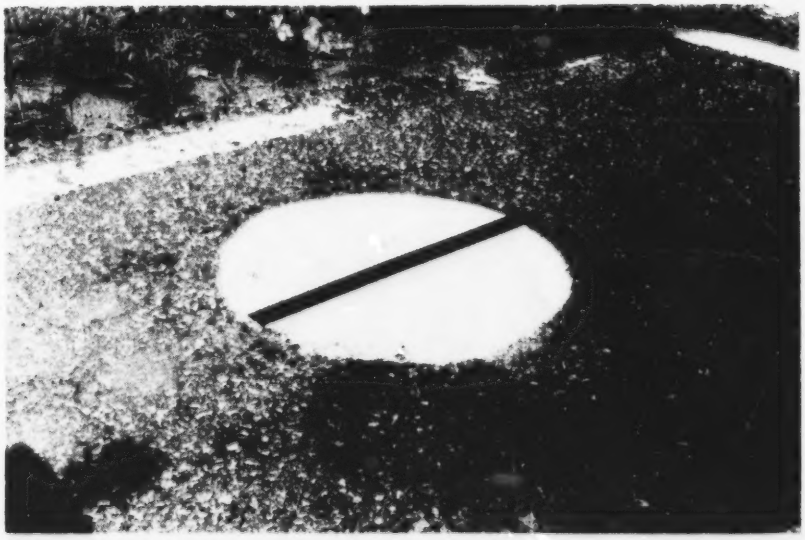


FIGURE J-3: MEASURING DIAMETER OF PATCH

APPENDIX J

BROCK ROAD NO. 4
TEXTURE DEPTH MEASUREMENTS
OUTSIDE WHEEL PATH

#1	5.02 mm	#2	3.88 mm
#3	5.09 mm	#4	4.50 mm
#5	4.21 mm	#6	3.86 mm
#7	4.56 mm	#8	3.93 mm
#9	4.21 mm	#10	4.30 mm
#11	4.71 mm	#12	4.50 mm
#13	4.84 mm	#14	4.41 mm
#15	3.20 mm	#16	3.44 mm
#17	3.27 mm	#18	3.23 mm
#19	3.27 mm	#20	3.08 mm

MODIFIED SINGLE SURFACE TREATMENT

N.Bound	$x = 4.20$ mm	$\sigma = 0.30$	$n = 7$
S.Bound	$x = 4.66$ mm	$\sigma = 0.36$	$n = 7$
N.& S.Bound	$x = 4.43$ mm	$\sigma = 0.40$	$n = 14$

DOUBLE SURFACE TREATMENT

N.Bound	$x = 3.25$ mm	$\sigma = 0.18$	$n = 3$
S.Bound	$x = 3.25$ mm	$\sigma = 0.04$	$n = 3$
N.& S.Bound	$x = 3.25$ mm	$\sigma = 0.12$	$n = 6$

X = TD (Texture Depth)

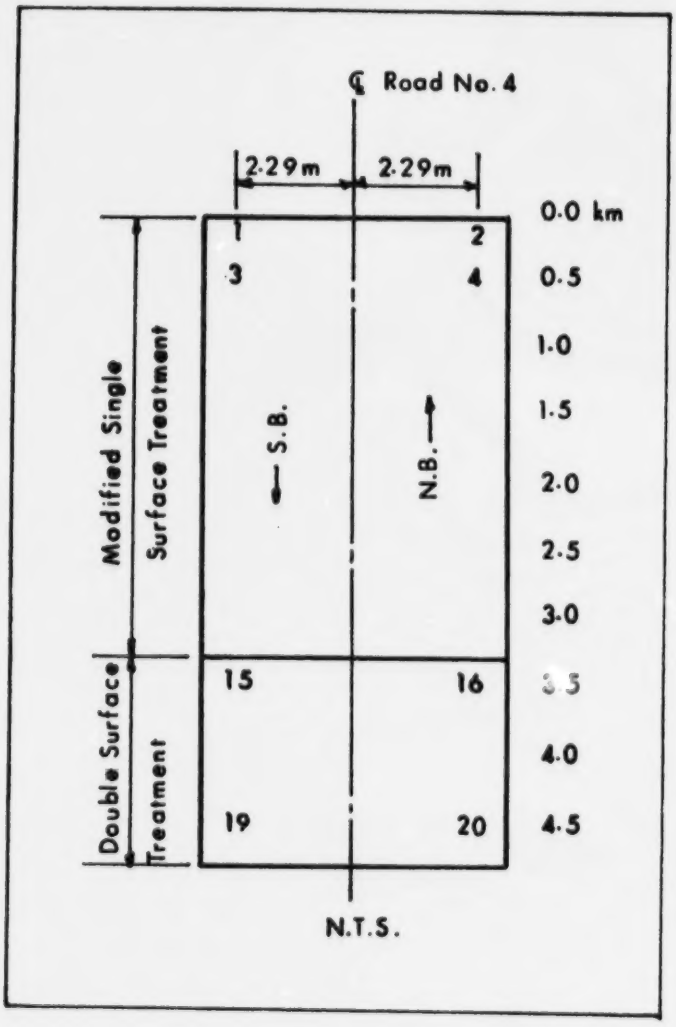


FIGURE J-1: LOCATION OF TEXTURE DEPTH MEASUREMENTS

MILLGROVE ROAD #21 - Class 1 SST
0.5 km East of Jct. Rd. #21 and Rd. #4

E.B. Lane, Outside Wheel Pass
TD = 3.463 mm

W.B. Lane, Outside Wheel Pass
TD = 3.066 mm

Mean = 3.3 mm

BROCK ROAD - HL-3
South of D.S.T.

TD = 0.67 mm

Attachment to MI-51 -
Modified Single Surface Treatment Using
12-19 and 4-9 mm Steel Slag Aggregate

SKID RESISTANCE TEST RESULTS

Location	Type of Pavement	SN_{80} km/h (Range)	
		1982	1983
Regional Road No. 4, Hamilton-Wentworth	Modified Single Surface Treatment With Steel Slag	48.6	45.0
"	Double Surface Treatment With Steel Slag	46.9	40.9
"	HL-3 Surface Course With Limestone Coarse Aggregate	25.9	24.3
Regional Road No. 21, Hamilton-Wentworth	Standard Single Surface Treatment With Quarried Limestone Chips (9 mm)	45.8	37.8
King's Hwy. #5	HL-1 Surface Course With Steel Slag Coarse Aggregate	34.2	35.5

NOISE LEVEL, REGIONAL ROAD NO. 4

Traffic Condition	Increase in Sound Levels Due to the Change From Typical Hot Mix HL-3 to Surface Treatment, Slag	
	1982	1983
Average operating speed of cars as well as trucks, 80-100 km/h, 10 to 20% of trucks	5 dBA[1]	
Cars only at 80 to 100 km/h	7 dBA[1]	
Average operating speed of cars 70-80 km/h, trucks 60-70 km/h, 10% medium trucks, 10% heavy trucks	2 dBA[2]	1 dBA[2,3]
Cars only at 70 to 80 km/h	5 dBA[2]	4.5 dBA[2,3]

1. Increase based on speed, traffic composition and previous experience.

2. Actually measured values at Regional Road No. 4.

3. The sound level difference of 1 dBA is considered the smallest perceivable difference.

TEXTURE DEPTH RESULTS

Location	Type of Pavement	Texture Depth, mm	
		1982	1983
Regional Road No. 4, Hamilton-Wentworth	Modified Single Surface Treatment With Steel Slag	4.43	2.90[1]
"	Double Surface Treatment With Steel Slag	3.25	2.56
"	HL-3 Surface Course With Limestone Coarse Aggregate	0.67	0.54
Regional Road No. 21, Hamilton-Wentworth	Standard Single Surface With Quarried Limestone Chips (9 mm)	3.30	2.61

1. Four texture depth measurements in the northbound lane were eliminated due to localized flushing in the outside wheel track.

SKID RESISTANCE DATA

Hwy No. Reg. Rd. 504

Location Hwy. 5 to Sixth Concession

Date 83 06 23

Direction Southbound

Lane No. Driving Lane

NORTH

OFFSET	SPEED	SN	INTERSECTION
0.00			Highway 5
1.13			Pavement Change
1.25	77.2	23.2	
1.46	79.1	23.2	SN_{80} = 20.8
1.58	80.6	18.9	
1.75	80.9	20.2	
1.83			Pavement Change
1.88	80.3	42.1	
2.12	77.9	39.5	
2.27	76.5	36.7	SN_{80} = 38.3
2.33			4th Concession
2.47	78.7	34.8	
2.64	77.7	33.9	
2.90	75.9	43.6	
3.00			Pavement Change
3.13	76.9	43.8	
3.32	78.9	46.3	
3.62	79.1	44.5	
3.88	78.9	44.6	
4.20	78.5	38.8	
4.29			5th Concession
4.52	79.1	42.6	
5.18	78.3	42.8	SN_{80} = 43.7
5.43	77.6	46.7	
5.60	78.3	45.7	
5.78	78.6	46.6	
5.92	79.6	44.7	
6.14	79.2	42.2	
6.21			Pavement Change
6.23			6th Concession

SKID RESISTANCE DATA

Hwy No. Reg. Rd. 504

Location Highway 5 to Sixth Concession

Date 83 06 23

Direction Northbound

Lane No. Driving Lane

NORTH

OFFSET	SPEED	SN	INTERSECTION
0.00			Highway 5
0.96	84.2	38.4	
1.13			Pavement Change
1.21	88.0	24.2	
1.36	79.9	25.4	
1.49	78.4	29.0	SN_{80} = 27.7
1.66	79.4	29.8	
1.77	80.6	27.0	
1.83			Pavement Change
1.90	80.1	48.2	
2.00	77.9	43.8	
2.12	77.5	43.5	
2.24	76.8	43.8	
2.32			4th Concession
2.39	77.0	40.9	
2.51	76.5	42.7	SN_{80} = 43.5
2.66	78.3	43.9	
2.80	79.7	43.1	
2.96	81.3	41.4	
3.00			Pavement Change
3.09	81.4	46.0	
3.23	82.6	45.4	
3.40	83.3	45.9	
3.59	82.8	49.3	
3.80	81.4	48.7	SN_{80} = 46.2
4.05	81.6	47.8	
4.29			5th Concession
4.44	80.3	42.1	
4.62	79.4	44.6	
4.78	78.7	44.0	
4.93	78.8	46.2	
5.11	78.5	47.2	
5.36	80.6	47.6	
5.66	79.0	47.8	
5.95	78.4	43.9	
6.21			Pavement Change
6.23			6th Concession

SKID RESISTANCE DATA

6

Hwy No. HAMILTON WENTWORTH REG. 21

Location HWY. 6 TO REG. 4

Date 83 06 23

Direction WESTBOUND

Lane No. DRIVING LANE

EAST

OFFSET	SPEED	SN	INTERSECTION
0.00			Reg. 4
0.20	79.5	39.5	
0.59	80.3	40.8	
0.96	81.0	36.9	
1.21	82.3	39.3	
1.54	76.1	39.5	
1.86	82.7	42.7	
2.12	84.7	41.0	
2.45	79.1	40.7	
2.70	78.4	37.9	
2.97	75.7	37.0	
3.24	77.5	36.2	
4.38			"60 km/hr Begins"
5.33			Hwy. 6

OVERALL SN_{80}=39.3

SKID RESISTANCE DATA

Hwy No. HAMILTON WENTWORTH REG. 21

Location HWY. 6 TO REG. 4

Date 83 06 23

Direction EASTBOUND

Lane No. DRIVING LANE

EAST

OFFSET	SPEED	SN	INTERSECTION
0.00			Reg. 4
0.45	81.3	34.0	
0.70	86.4	31.0	
1.33	81.4	39.7	
1.95	80.6	37.9	
2.57	77.2	41.7	
2.72	78.2	33.9	
3.07	77.3	34.8	
3.33	76.0	37.5	
3.61	77.1	39.0	
3.97	81.9	34.3	
4.26	81.4	36.2	
4.38			"60 km/hr Begins"
5.33			Hwy. 6

OVERALL SN_{80}=36.3

SKID RESISTANCE DATA

8

Hwy No. 5

Location HAMILTON - HWY. 6 TO HALTON REG. 4

Date 83 06 23

Direction EASTBOUND

Lane No. DRIVING LANE

EAST

OFFSET	SPEED	SN	INTERSECTION
0.00			Reg. 4
0.13			Pavement Change
0.26			Moxley Road
0.34	82.1	38.6	
0.67	79.9	35.5	
1.04	79.3	36.8	SN_{80}=37.0
1.55	78.7	37.2	
1.68			Ofield Road S
1.88			Ofield Road N
2.07	84.6	33.0	
2.47	81.4	35.0	
3.04	78.8	35.0	
3.15			Mazza Avenue
3.60	80.7	32.4	
3.96	79.7	33.9	SN_{80}=34.5
4.11			Sydenham
4.31			Millgrove Sideroad
4.63	79.4	35.6	
5.08	79.1	34.9	
5.32			Rock Chapel Road
5.58	79.4	36.1	
5.95			Algonquin Avenue
6.04	77.1	34.1	
6.66	76.7	37.0	
6.94	71.1	38.4	SN_{80}=35.6
7.07	73.6	35.7	
7.13			Hwy. 6

OVERALL SN_{80}=35.3

SKID RESISTANCE DATA

Hwy No. 5

Location HAMILTON - HWY. 6 TO HALTON REG. 4

Date 83 06 23

Direction WESTBOUND

Lane No. DRIVING LANE

EAST

OFFSET	SPEED	SN	INTERSECTION
0.00			Reg. 4
0.13			Pavement Change
0.16	75.1	36.0	
0.26			Moxley Road
0.32	77.3	37.4	
0.84	79.9	37.7	
1.39	77.8	39.0	
1.68			Ofield Road S
1.81	77.6	34.9	
1.88			Ofield Road N
2.25	81.9	35.9	
2.82	79.5	35.6	
3.16			Mazza Avenue
3.23	79.9	36.3	
3.80	81.6	36.6	
4.11			Sydenham
4.16	76.3	40.2	
4.30			Millgrove Sideroad
4.70	80.6	36.7	
5.19	78.0	31.6	
5.33			Rock Chapel Road
5.96	78.7	33.4	
6.66	75.7	36.3	
7.07	77.4	24.8	
7.12	78.9	35.3	
7.14			Hwy. 6

OVERALL SN_{80}=35.6

RESEARCH AND DEVELOPMENT BRANCH

memorandum

10.

Ontario

To: Mr. J. A. Cooper,
Bituminous Section,
Engineering Materials Office,
Central Building, 3rd Floor,
Room 317.

Date: 83 06 01

RECEIVED
JUN 2 1983
BITUMINOUS SECTION

Re: Surface Treatment Sound Levels, Brock Road

This is a response to your request of 83 03 16 to re-evaluate sound generation potential of the surface treatment at the above site.

Summary

Measurements were done on two different days: April 8 and May 11, 1983. In general, the results were similar to those reported previously (83-12-02 and 82-11-22); however, it appears that the measured differences between the sound levels generated by the two pavements (surface treatment and HL-3 asphalt concrete) were somewhat smaller (by about 1 dBA) than the corresponding differences reported previously.

Results

The measurement procedure and equipment were quite similar to those used previously and described in my memorandum of 82-12-02. Three different sets of measurements were conducted.

1. Sound levels emitted by total (existing) traffic flow passing by on the two adjacent pavement sections. The surface treatment was about 1 dBA noisier than HL-3 surface. The corresponding previous result was about 1.5 dBA.

2. Sound levels emitted by only passenger cars passing by. The surface treatment was about 4.5 dBA noisier than HL-3 surface. The corresponding previous result was about 5.0 dBA. 1/3 octave band frequency spectra sound levels shown in Figure 1, are also quite similar to those reported before.

3. Sound levels emitted by a single vehicle (1980 Plymouth Horizon equipped with radial tires) passing at a constant speed of 80 km/h. The peak sound level on the surface treatment was about 5.5 dBA higher than the corresponding sound level on HL-3 surface. The previous result was about 8 dBA. Again, 1/3 octave band frequency spectra for the two pavements, given in Figure 2, have quite similar shape as their 1982 counterparts.

If you require additional information, or if you have any questions or concerns, please call me.

Enc. 2 Figures

cc: Messrs. F. W. Jung
G. J. Jones

J. J. Hajek,
Project Research Officer

J. Walsh,
Acoustics Research Technician

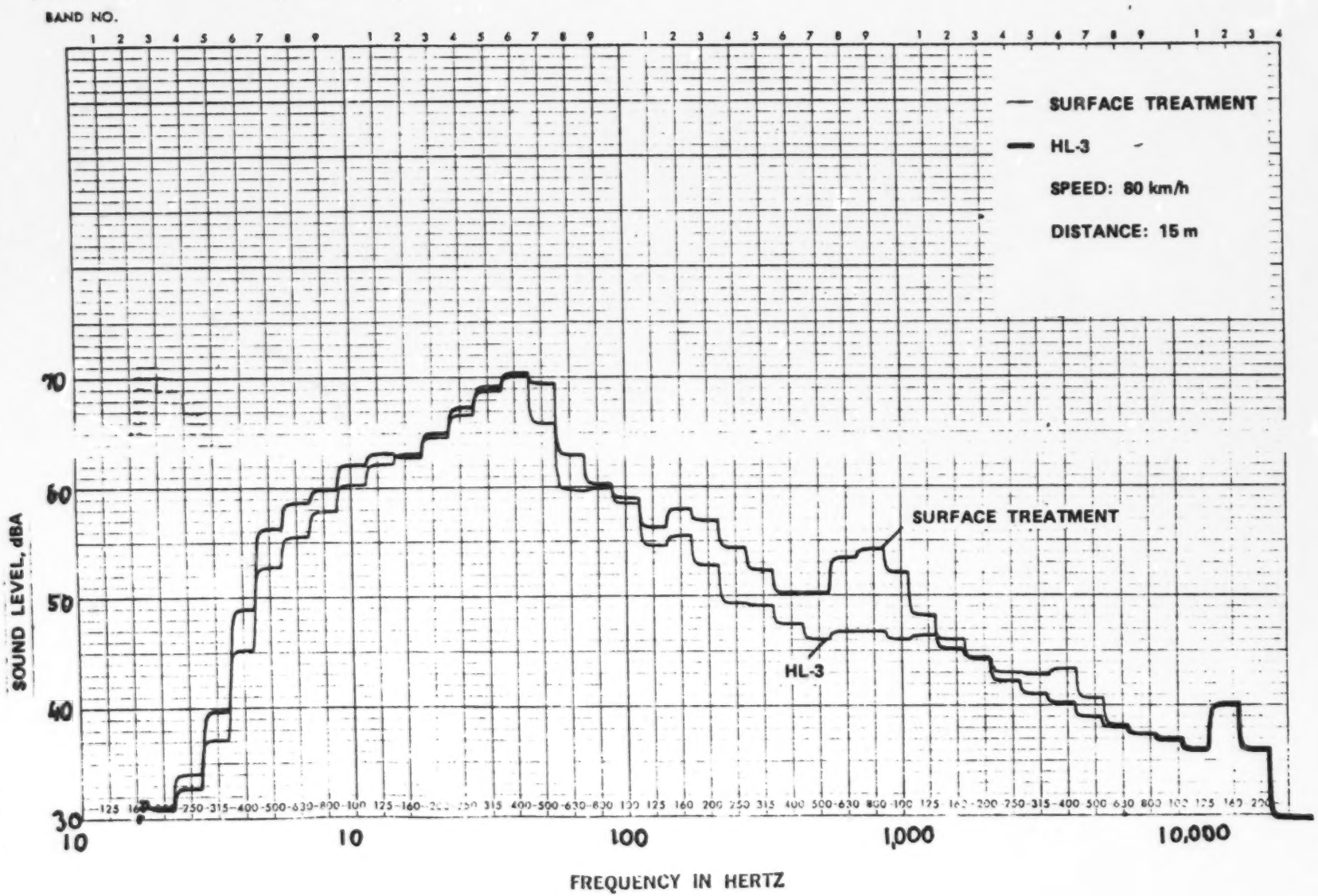


Figure 1/ Comparison of 1/3 Octave Band Frequency Spectra for Passenger Cars Only (15 m from Centreline, Brock Road, May 11, 1983).

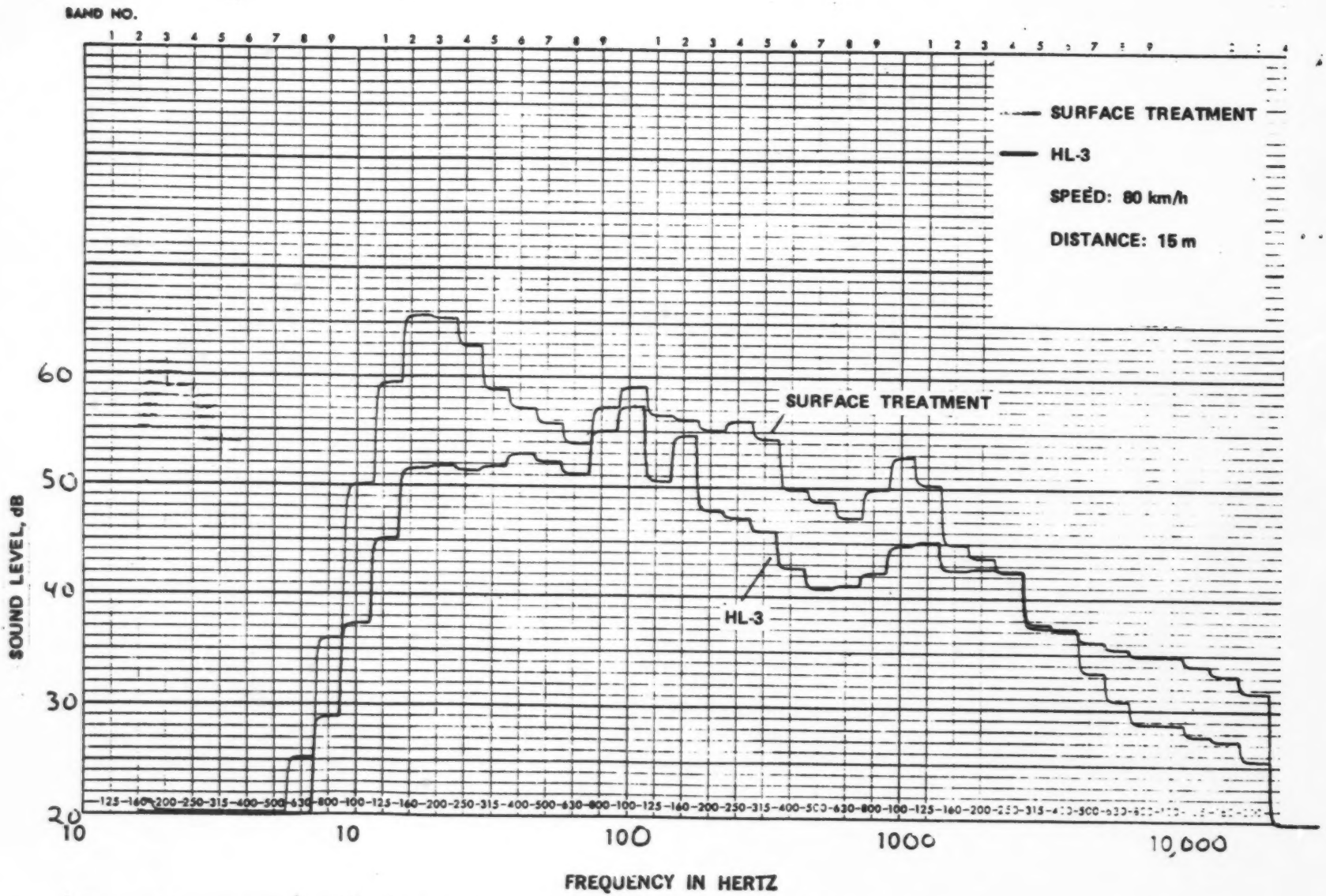


Figure 2/ Comparison of 1/3 Octave Band Frequency Spectra for 1980 Horizon (20 m from Centreline, Brock Road, April 8, 1983).

83 07 15

BROCK ROAD NO 4
TEXTURE DEPTH MEASUREMENTS, 1983
OUTSIDE WHEEL PATH

S. BOUND		N. BOUND		
1.	3.05 mm	2.	2.12 mm	MODIFIED S.S.T.
3.	2.97 mm	4.	2.23 mm	
5.	2.99 mm	6.	1.74 mm	
7.	3.12 mm	8.	1.80 mm	
9.	2.91 mm	10	2.20 mm	
11.	2.85 mm	12	2.90 mm	
13.	3.19 mm	14	2.85 mm	
15.	2.67 mm	16	2.82 mm	D.S.T.
17.	2.20 mm	18.	2.51 mm	
19.	2.64 mm	20.	2.54 mm	
21.	0.59 mm	22.	0.53 mm	HL3 BROCK ROAD
23.	0.52 mm	24.	0.53 mm	
E. BOUND		W. BOUND		
1.	2.37 mm	2.	2.47 mm	CLASS I SST. MILLGROVE RD.
3.	2.66 mm	4.	2.92 mm	

MODIFIED SST.

N. BOUND	$\bar{x}$ = 2.26 mm	σ = 0.46	n = 7
S. BOUND	$\bar{x}$ = 3.01 mm	σ = 0.12	n = 7
N&S BOUND	$\bar{x}$ = 2.64 mm	σ = 0.50	n = 14

D.S.T.

N. BOUND	$\bar{x}$ = 2.62 mm	σ = 0.17	n = 3
S. BOUND	$\bar{x}$ = 2.50 mm	σ = 0.26	n = 3
N& S. BOUND	$\bar{x}$ = 2.56 mm	σ = 0.21	n = 6

HL 3 BROCK ROAD

N. BOUND	$\bar{x}$ = 0.56 mm	σ = 0.05	n = 2
S. BOUND	$\bar{x}$ = 0.53 mm	σ = 0.00	n = 2
N&S BOUND	$\bar{x}$ = 0.54 mm	σ = 0.03	n = 4

CLASS I SST. MILLGROVE ROAD

E. BOUND	$\bar{x}$ = 2.52 mm	σ = 0.21	n = 2
W. BOUND	$\bar{x}$ = 2.70 mm	σ = 0.32	n = 2
E&W BOUND	$\bar{x}$ = 2.61 mm	σ = 0.24	n = 4

NOTE
1. THE OUTSIDE WHEEL PATH OF THE W. BOUND LANE WAS SLIGHTLY FLUSHED RESULTING IN LOWER T.D. VALUES.